High Rate Data Delivery Thrust Area

Technology Strategy Team Meeting
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Outline

- **Program Architecture**
  - Historical Perspective
  - Goals and Objectives
  - Program Architecture and Investment Strategy
  - Participating Centers/Partners
- **Current and Planned Products**
- **Summary**

Historical Perspective

- NASA's Space Communications Research and Development Program's responsibility was to open new frequency bands and provide enabling technology in direct support of US satellite industry competitiveness and NASA missions from 1978 under Code R and Code S. Since 1992, the program has been managed by Code X.

- Following the dissolution of Code X, communications technology responsibility was transferred to Code SM (CETDP), while the ACTS Project, studies and Spectrum Management functions were transferred to Code M (SOMO). The program under CETDP was titled "High Rate Data Delivery (HRDD)" as a Thrust Area. This Thrust Area was assigned to Glenn.

- HRDD funding now is being driven by metrics to lower TRL; and measured by its relevance to SS, ESE and HEDS enterprises. In addition, due to the development of Internet, communication technologies are going through major paradigm shift.

High Rate Data Delivery Program

Goal: Develop innovative products which provide end to end information delivery solutions to meet NASA enterprises emerging need of space communication architectures beyond 2005.

Technology Development:

- **Ka-Band Amplifiers, Receivers, Modems, Antennas**
- **Optical Technologies - 1st Generation**
- **Internet Protocols and Network Technologies Space Environment**
- **Hyperspectral Imaging**

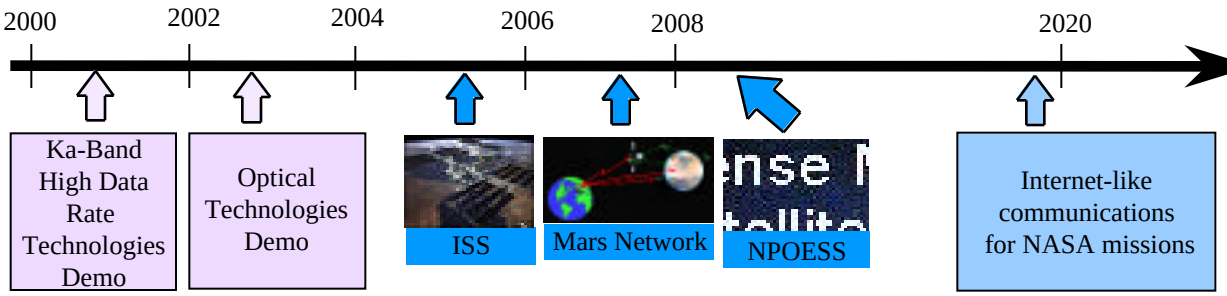
- **On-Board Processing**
- **Multicasting Networks**
- **Low Cost, Miniature, Low Power Integrated Components**
- **10 Gbit-Rate Comm. Systems**
- **Ad-Hoc Networks for Multiple Spacecrafts**

- **Seamless High Data Rate Information Delivery**
- **Intelligent, Ad-Hoc User-Centric Communication Networks**
- **Communication Technologies for Multiple Spacecraft Networks Connected to Deep Space Backbone**

Capabilities:

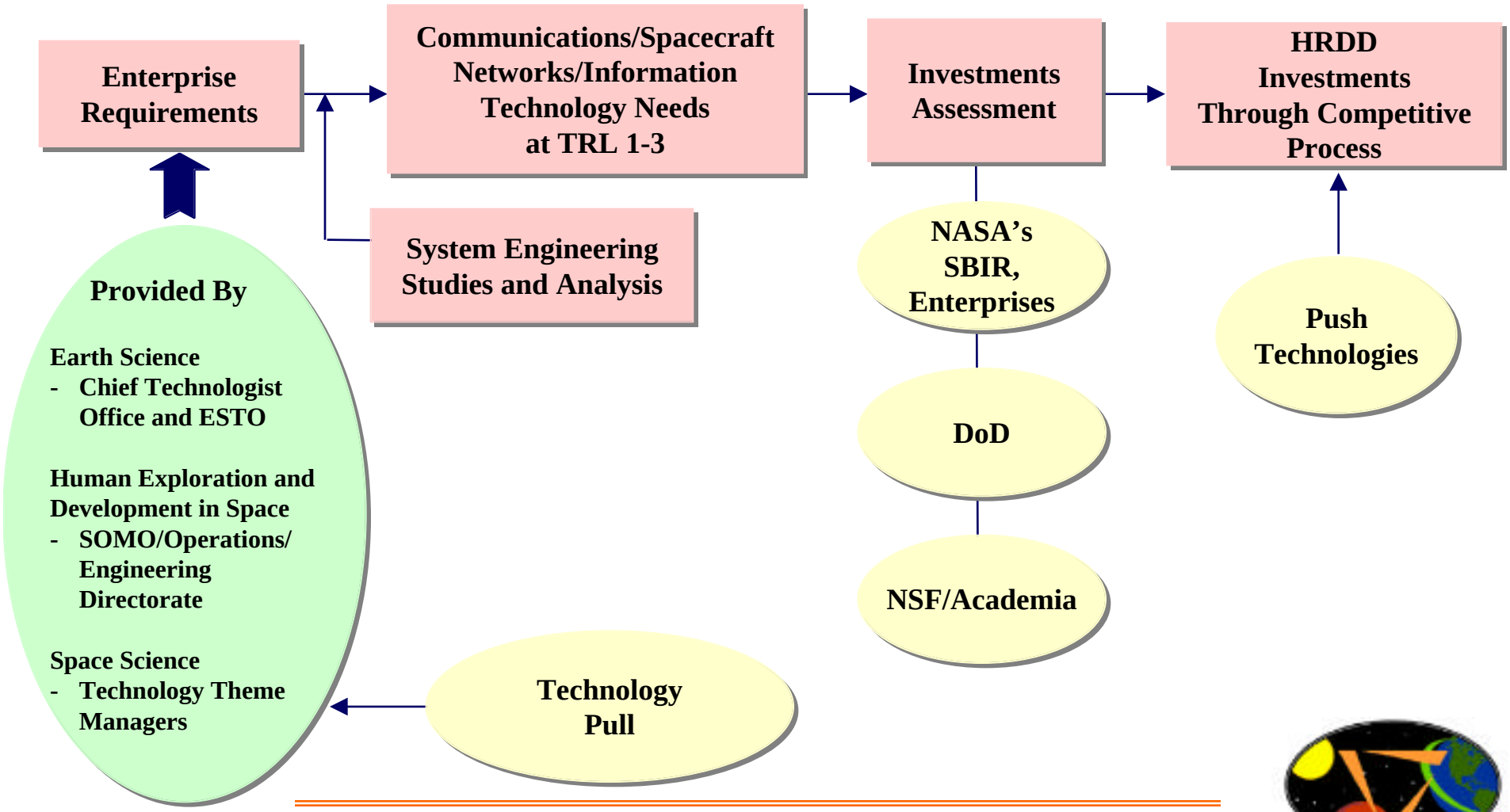
Point-to-Point Communications → **Point-to-Multipoint Communications** → **Autonomous, Ad-Hoc Multiple Comm.**

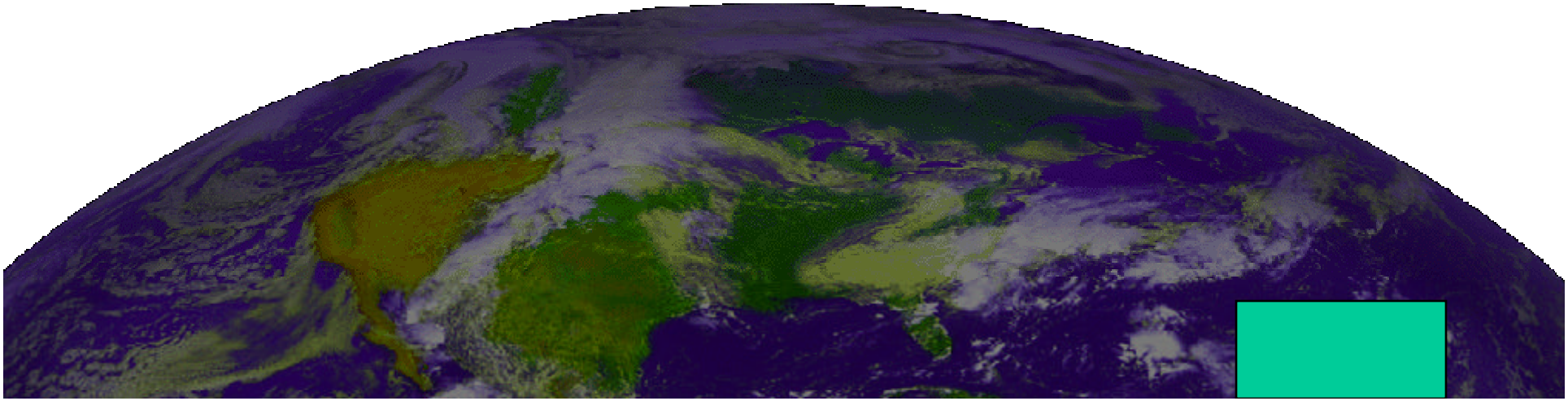
Demos/Missions:



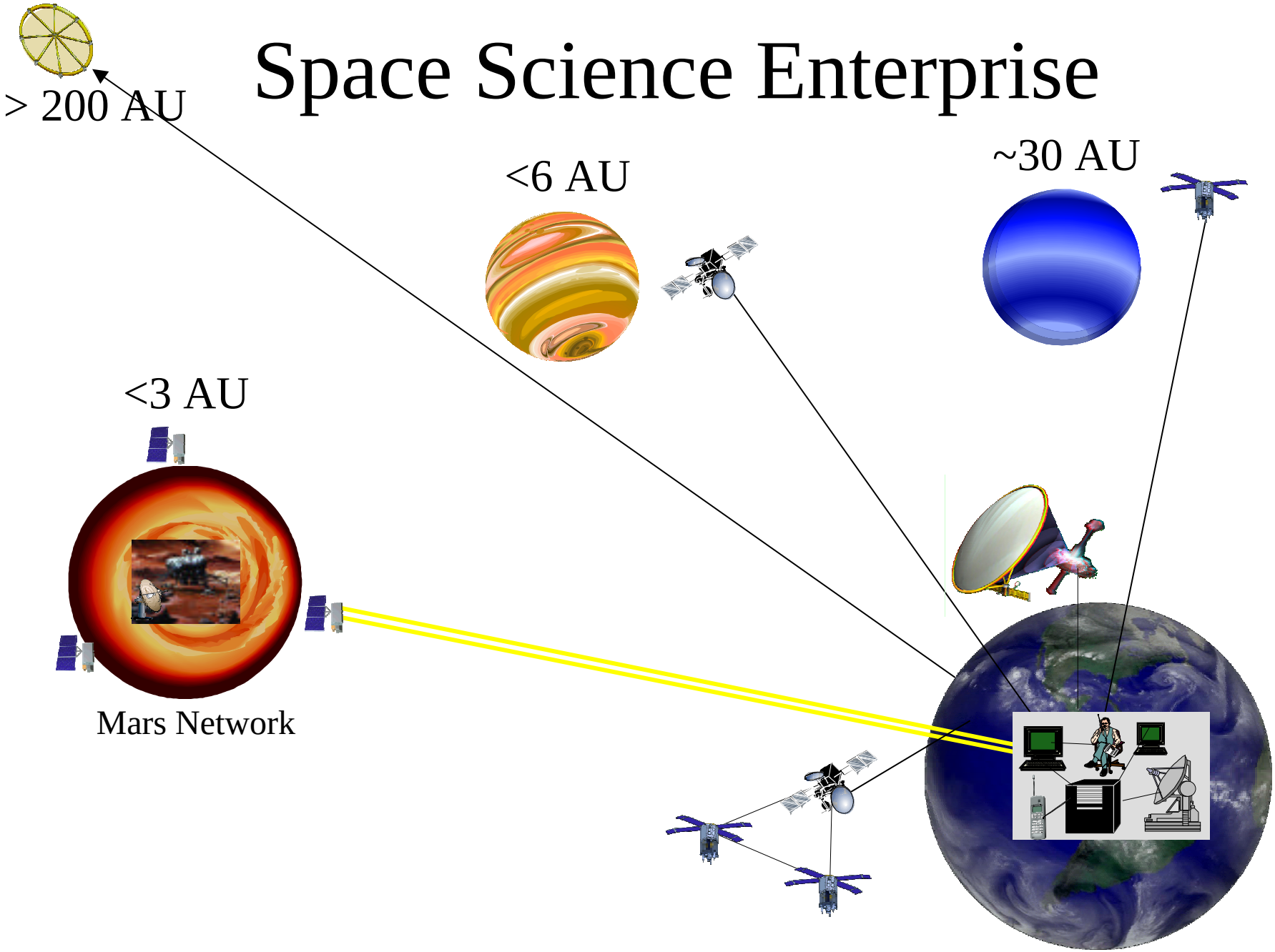
High Rate Data Delivery Thrust Area in Space Based Technology Program

HRDD Thrust Area Technology Investment Process

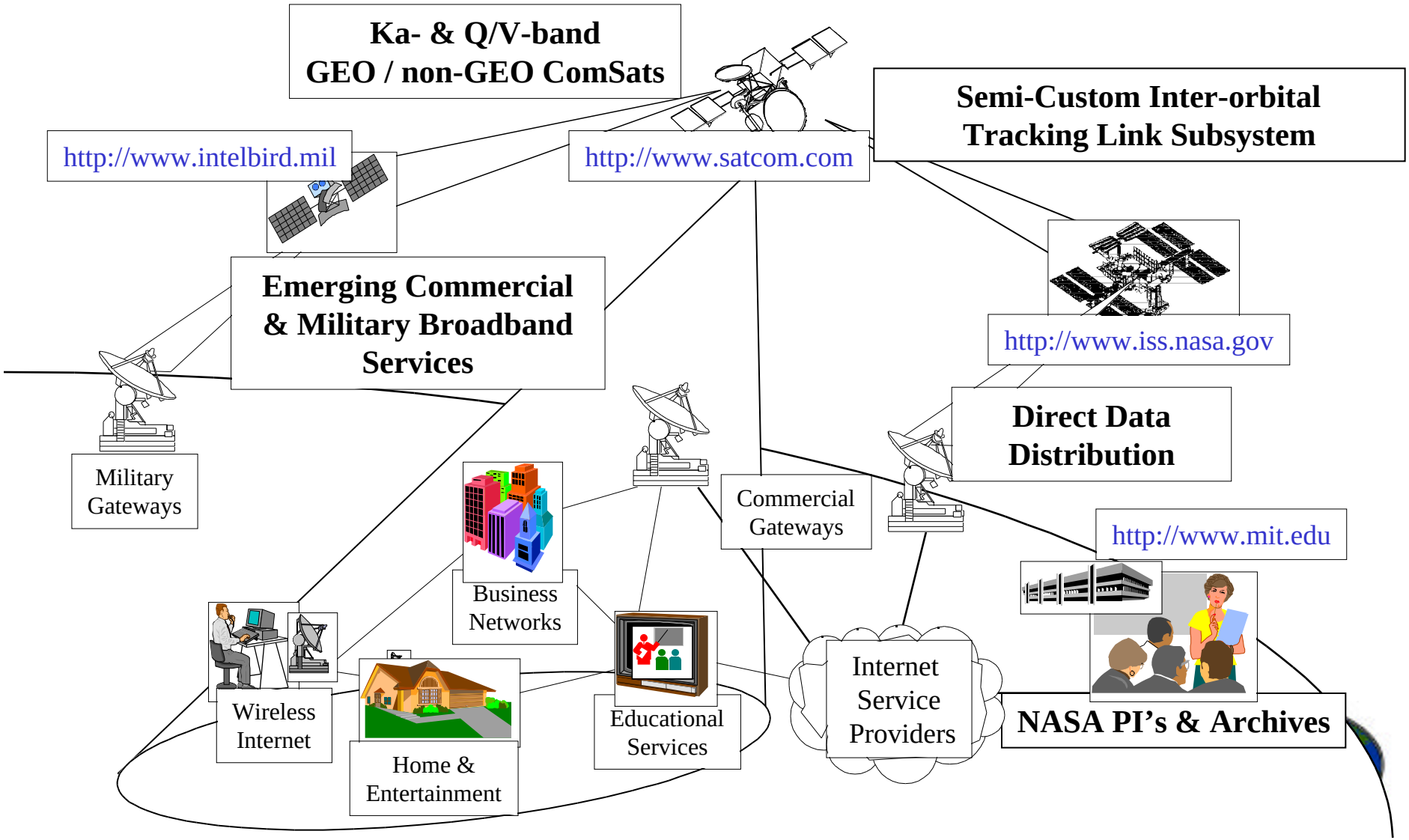




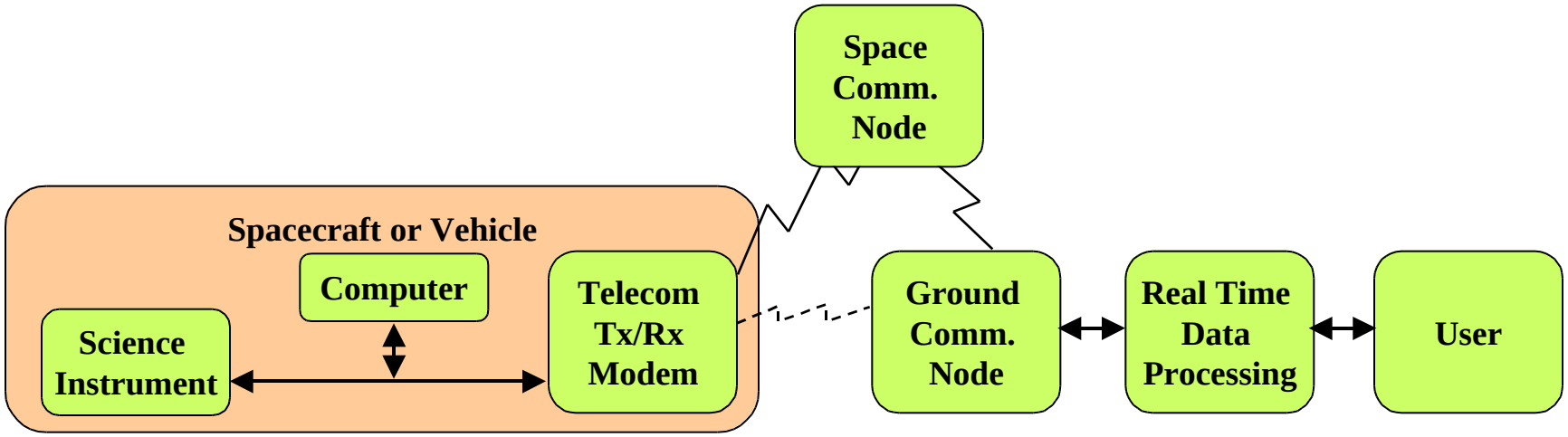
Space Science Enterprise



HEDS Enterprise



Studies of End-to-End Solutions



- Deep Space Communications (JPL)
- Access Network (JPL)
- IP Based Satellite Accommodation Study
  (Rapid 2 Contract jointly funded by ESTO and SOMO)
- Backbone network Study
  (Lockheed Martin jointly funded by ESTO)

Example - Mars Backbone Network Roadmap

Technology Areas: **High Data Rate Backbone Between Earth and Mars**

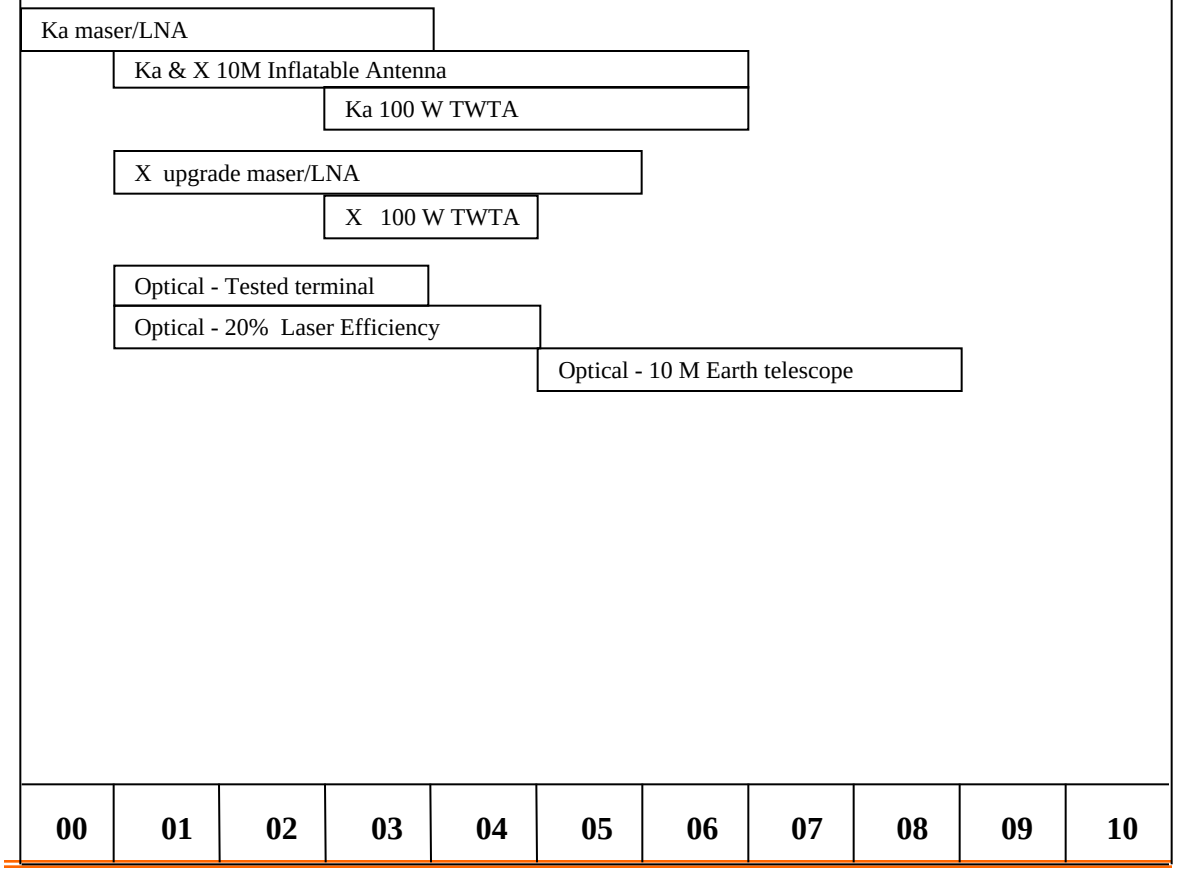
- **Ka-, X-band In-Space RF Hardware - Rx/Tx, Modem, Antennas**
- **Optical Link Hardware**
- **In-space Network Switches**
- **In-space Server Functions**
- **Autonomous Control Software**
- **Up-grades to DSN**

Technology Project

High Rate Relay
- **Ka-, X-band HW**
- **Optical Link HW**
- **Antenna**
- **Gnd**
- **Modem**
- **Protocol & coding**
- **Network/Server HW**
- **Autonomy**

Low Rate Critical Events
- **Ka, X, W**
- **Optical**
- **Antenna**

Services Provided
- **Aereo Positioning System (APS)**
- **Doppler & Ranging services**
- **'Lighthouse' beacon services**



Goals

High Rate Relay
- **RF 2.7 AU: >100 Mbps**
- **Opt 2.7 AU: >40-275Mbps**
- **Ant. Size: 10 M**
- **Ant mass: < ?? kg**
- **Power >100 W**
- **Efficiency >45%**
- **Pointing <0.0??°**

Low Rate Critical
- **RF 2.7 AU 10-100 bps**
- **Optical 25 bps**
- **Omni 0db**
- **Power >100 W**

Service Goals
- **Service on demand**
- **Service 4 surface items at a time.**
- **Enable autonomous vehicles to self navigate**

High Rate Data Delivery Thrust Area in Space Based Technology Program

Partners

University	Industry	Enterprise	Agencies
• Univ. of Michigan • Univ. of Colorado • Cleveland State • Georgia Institute of Technology • Univ. of Dayton • Ohio University • UCLA • USC • Cal. Tech.	• Hughes • Lockheed Martin • Raytheon Systems Co. • Cisco Systems • Sandia National Labs • SiCOM, Inc. • IPG Photonic • Boeing	• GSFC • SOMO • JPL TMOD • ESTO	• DoD • NRO (potential)

High Capacity, High Rate Communication Distributed Network

Focused Activity at GRC

Goal:

- Provide revolutionary advancements of high capacity high rate space communication technologies capable of direct delivery of information to the user from NASA missions at multi-gigabit rates, while minimizing the cost and the impact of communication subsystem on future spacecraft.

  The current state of the art is 622 Mbps.

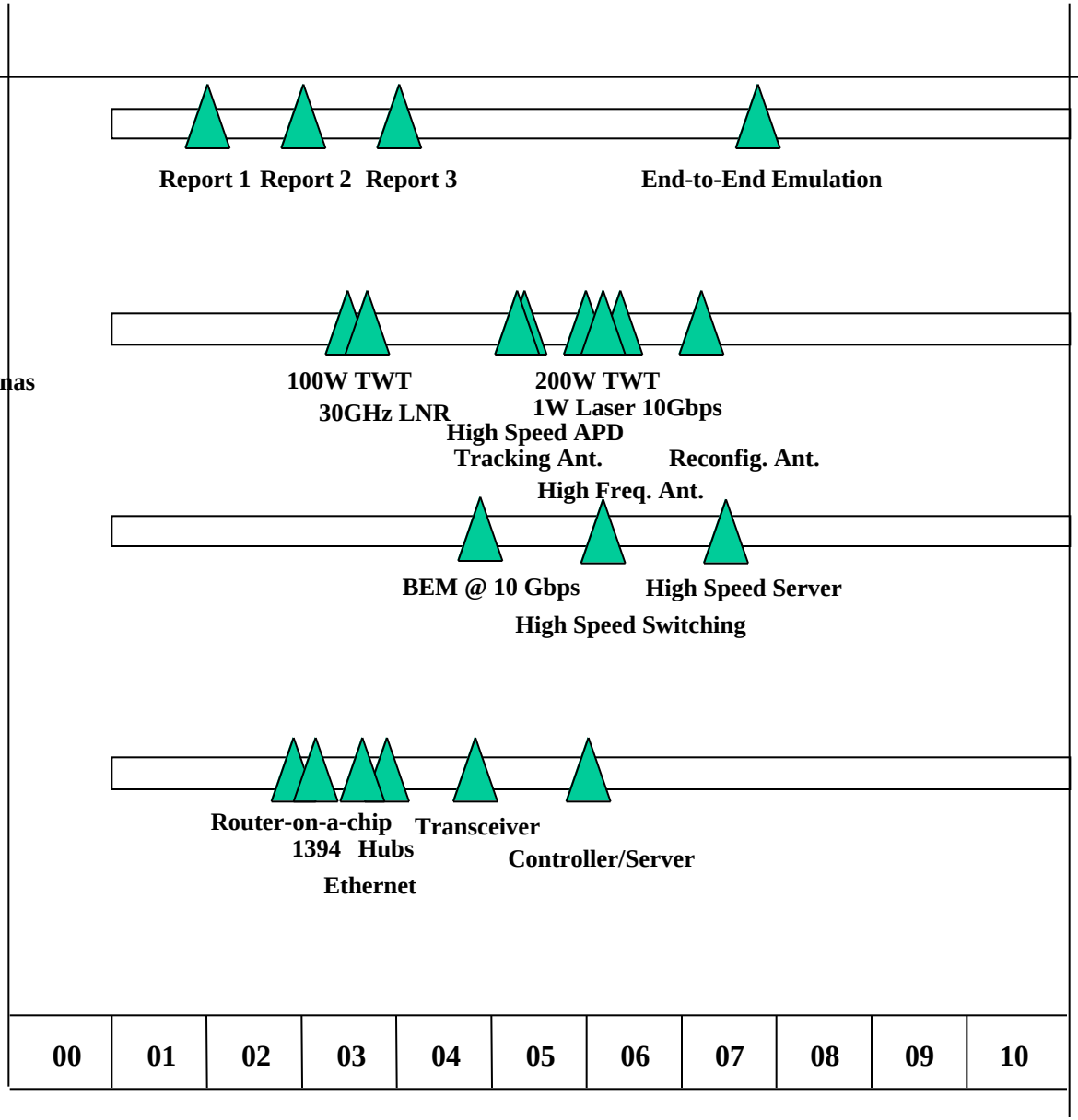
Approach:

- The future architecture technology needs and roadmaps will be developed by a system engineering approach jointly with the industry.
- The program will harvest new ideas/concepts from outside NASA especially the academic community combined with the in-house activities. Also will coordinate activities with other Government agencies.
- The program will continually seek new ideas/concepts for a second “wave” of technology candidates for funding in future years

High Capacity High Rate Communication
Distributed Network Focused Activities at GRC

Work Breakdown Structure

- **System Architecture Development**
  - System Studies/Simulation
  - IP bus architecture design
  - Link and capacity analyses
- **Multi-Gigabit Link**
  - High power transmitters
  - Ultra low power receivers
  - High precision µWave Antennas
- **High Capacity S/C Tech**
  - Multi-Gbps modems/coders
  - High connection count switches/routers/hubs
  - High speed servers
  - Algorithms & protocols
- **S/C Networking Tech**
  - Protocol Based Transceiver
  - Router-on-a-chip, Hubs
  - Network interfaces: IEEE 1355, 1394, Ethernet
  - Autonomous spacecraft controller/server
  - Algorithms & protocol

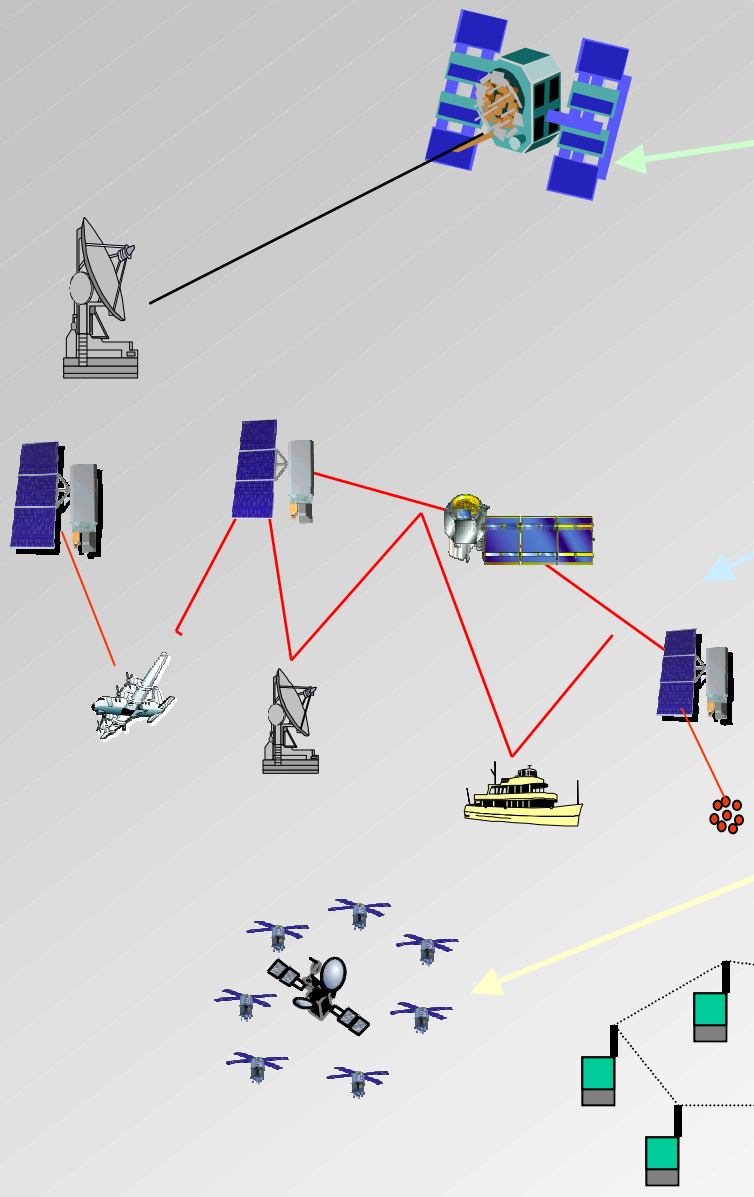


Goals

Develop System-level Architecture to provide:

- 1-100Gbps service
- Mobile handoffs
- Multiple access (100s of vehicles at a time)
- High latency store/forward
- Files and streaming data
- Service on demand (Strive for 'dial-up')
- Scheduled Service
- Prioritizing services
- Graduated QoS
- Security
- Power: >100W
- <0.1 AU 1-100Gbps
- <2.7 AU: >100 Mbps
- Power: <10W
- 2.7 AU: >1 Mbps
- 6 AU: >160 kbps
- 11 AU: >48 kbps
- 20 AU: >14 kbps
- Pointing: <0.05°,
- BW: >5-10%
- LAN: 1Gbps

Architecture Elements



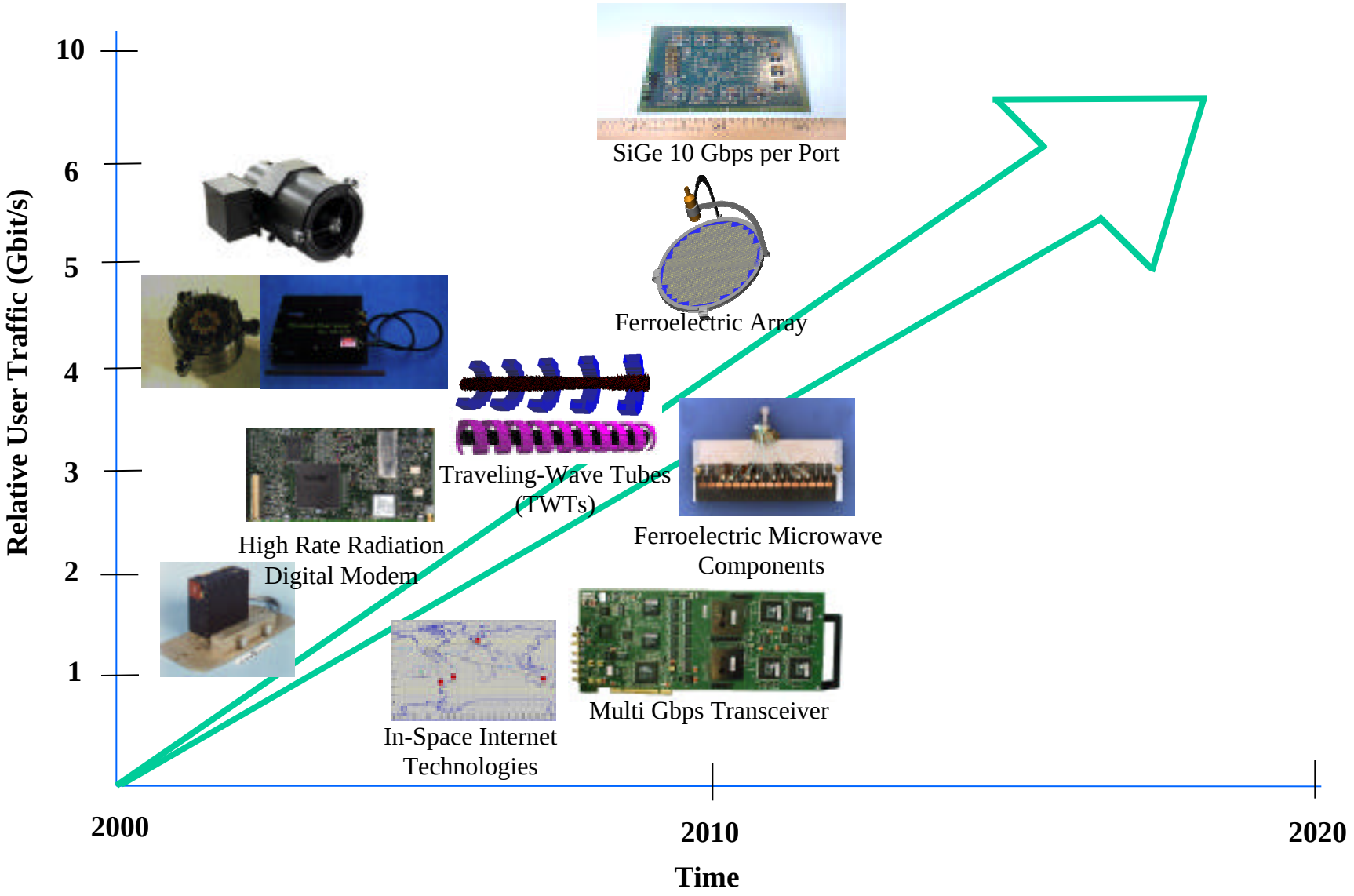
Backbone Networks
- Multi- Gigabit
- Seamless Interoperability
- Flexible
- Bandwidth Demand
- Internet-Like Communications

Access Networks
- Information, any where, any time to users
- IP spacecraft configurable system
- Integrated Multiple data for missions

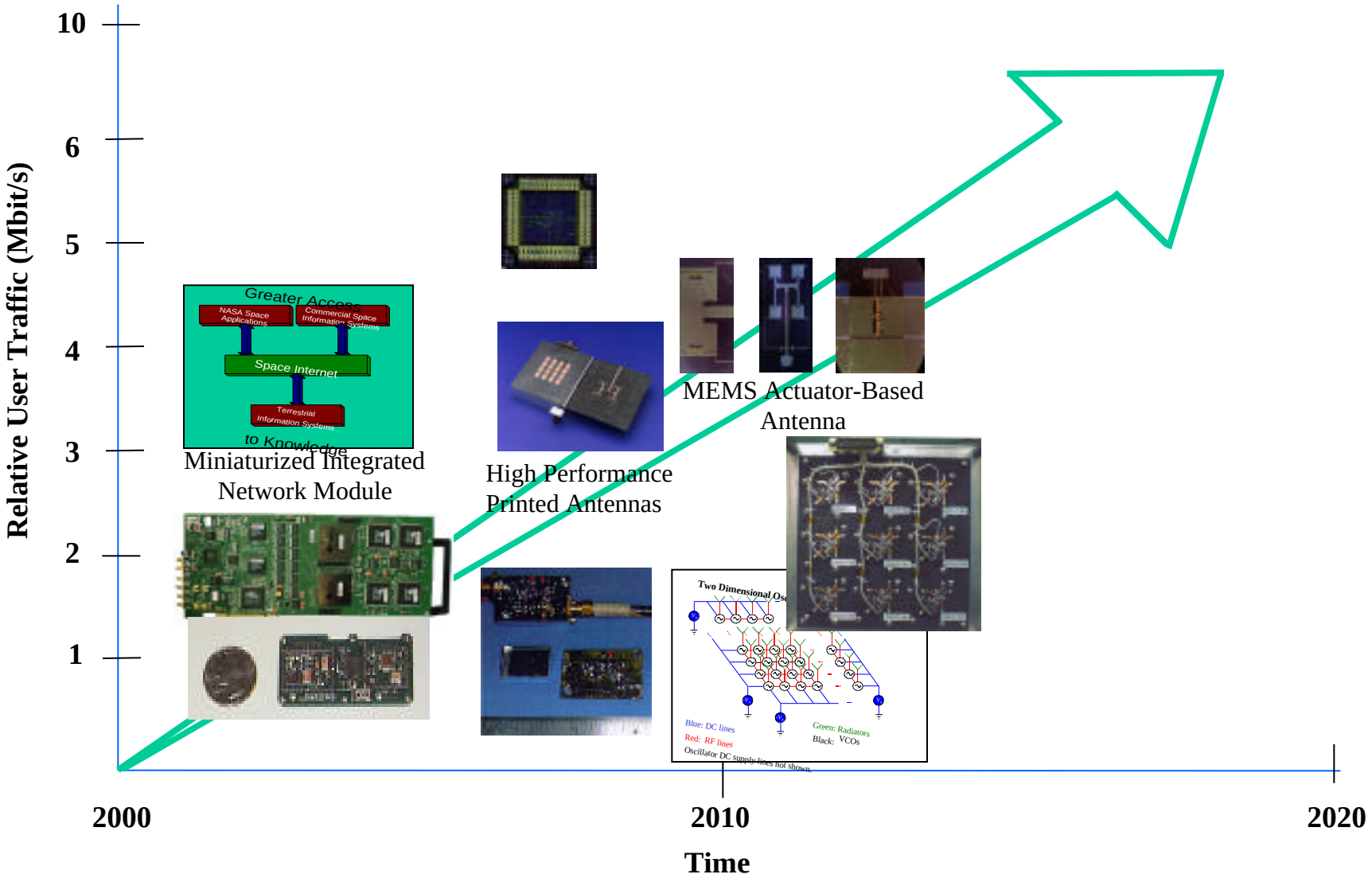
Inter-Spacecraft Networks
- Miniaturized microwave and network modules
- Standard Bus
- Wireless Internet
- Intelligent Networks

Proximity Wireless
- Ad Hoc
- Highly Efficient
- Long Life

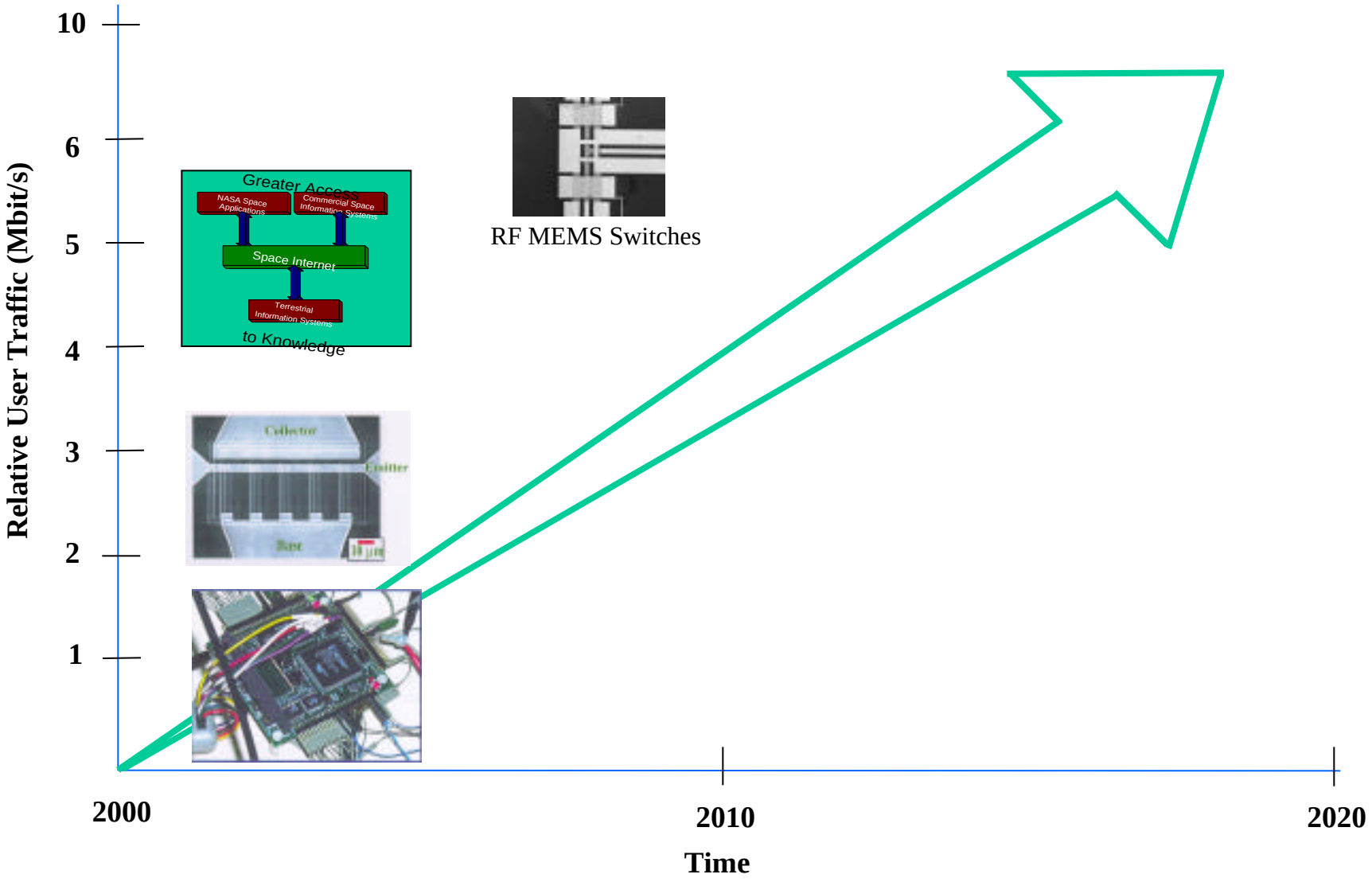
Backbone Networks



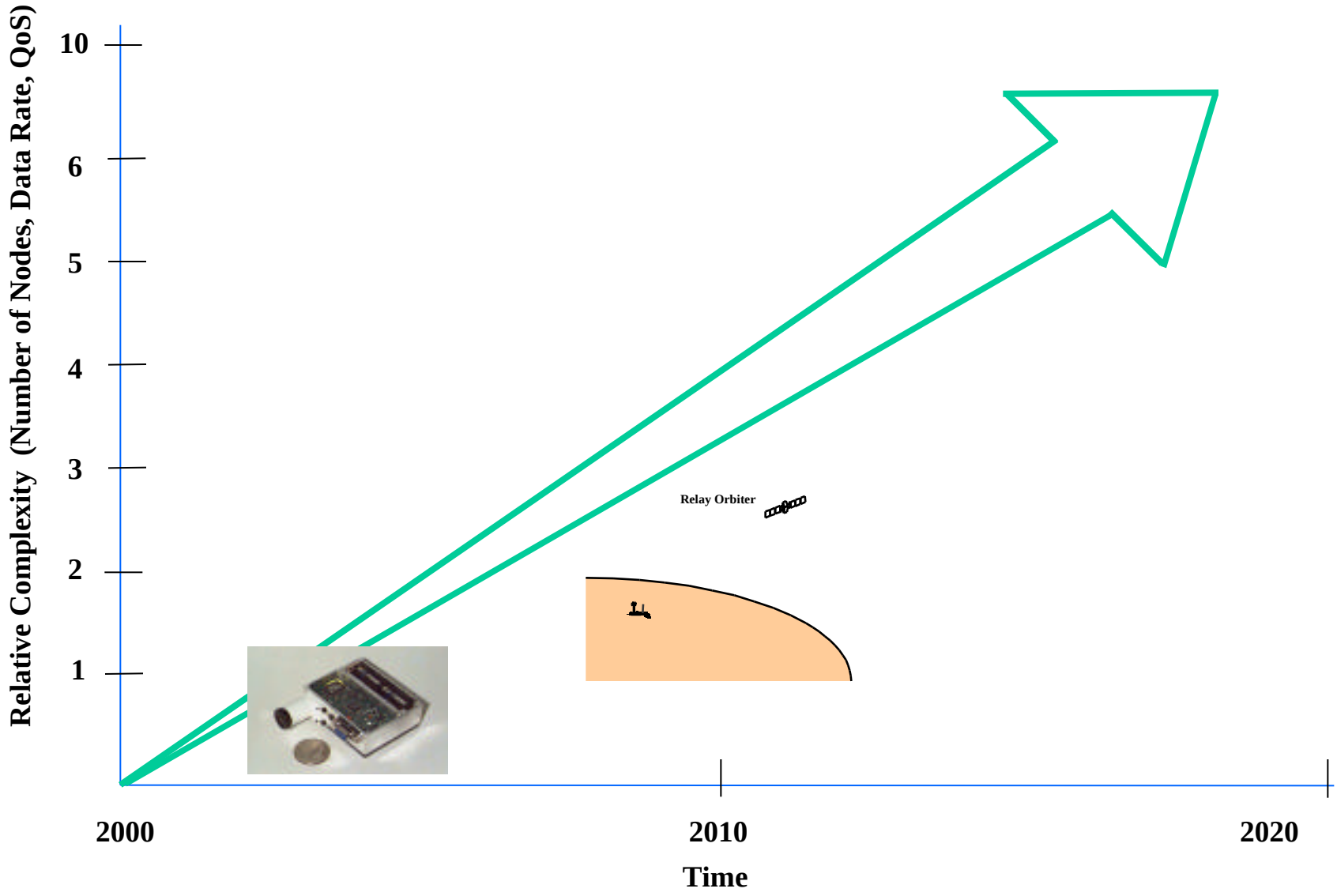
Access Networks



Inter-Spacecraft Networks



Proximity Wireless Networks



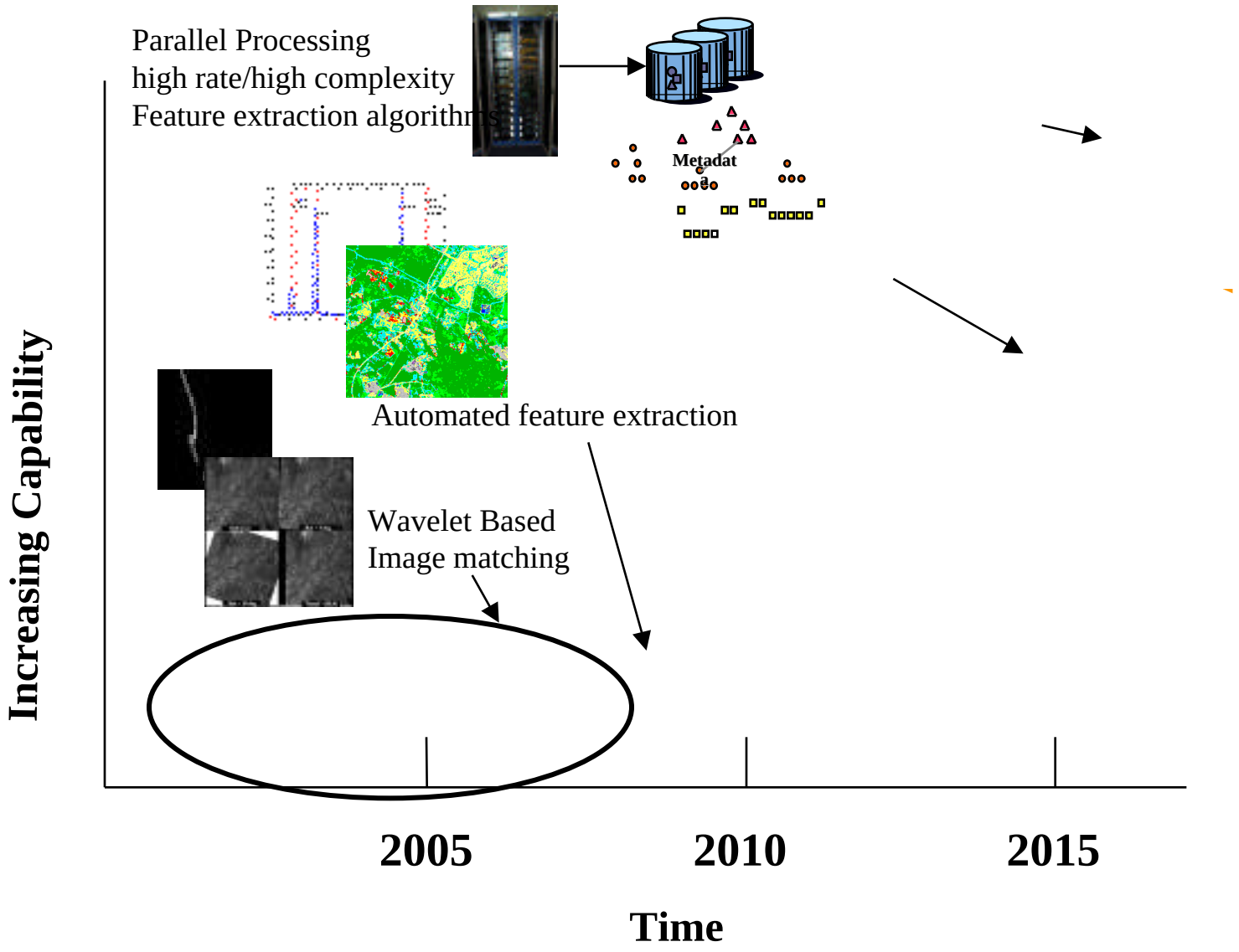
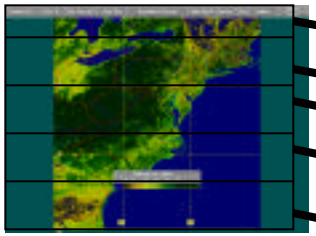
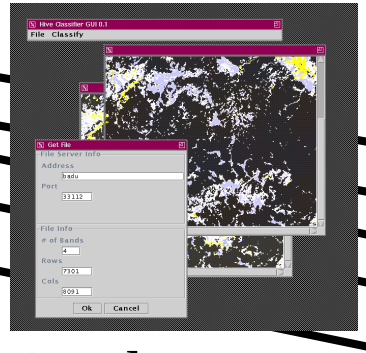

Parallel Processing
high rate/high complexity
Feature extraction algorithms
Metadat
Automated feature extraction
Wavelet Based
Image matching
Increasing Capability
2005
2010
2015
Time

Image Analysis Using Parallel Processing
Fundamental Description



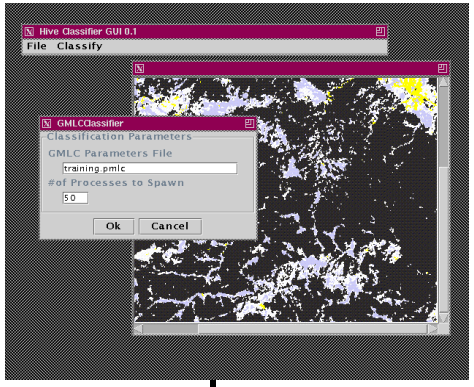
Break imagery into sections



Send separate sections to individual processors
4 to 128

Apply one algorithm per processor or a sequence of algorithms using more processors

Combine results
Results from each processor



To Storage/Retrieval and Distribution System

Technology Infusion

- In-Space Internet Technologies
- SiGe 10 Gbps Fast Packet Switch
- High Rate Radiation Hardened Digital Modem
- K-Band Phased Array Antenna
- Cryogenic Receiver Terminal
- Transport Protocol for Space-Based Internet
- HRIPDD Concept Prototype “Global View From Space”
- MCAS1 for Mars `03 Applications
- K-Band Propagation Characterization
- High Temperature Superconductivity TRP Program

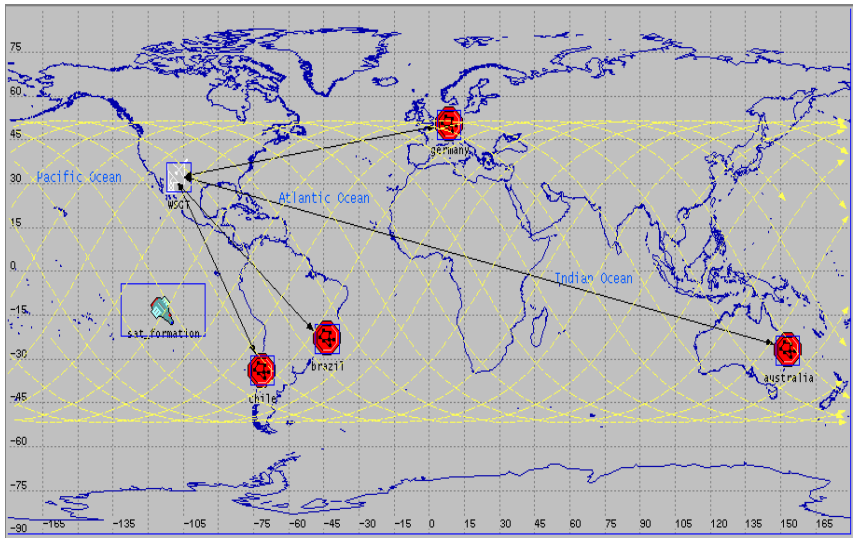
In-Space Internet Simulation Techniques Developed

Technology Goal

- To enable virtual presence for NASA's space-based research missions at lower cost and higher performance by improving accessibility, data integrity, and response times.

Approach

- Develop presently unavailable networking models to assess space-based, internet-like communications networks that are critical to the establishment of constellation and formation flying spacecraft communications.
- Evaluate seamless interoperability of future satellite and space platforms with terrestrial communication networks.

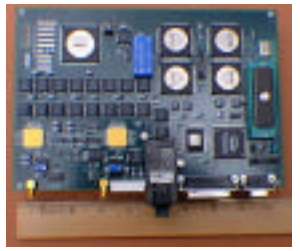


Accomplishment (FY00)

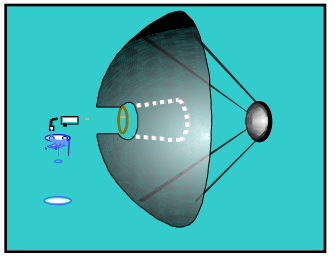
- A 3 satellite LEO formation/terrestrial OC-3 network Network/Node OPNET simulation model was developed and performance characteristics determined.
- Corresponding ISS Satellite Tool Kit link models have been developed.

622 Mb/s Communication Link Technologies for Direct Data Distribution

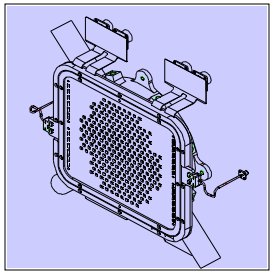
- **High Rate Modulation**
  - A radiation-hardened ASIC configurable to meet multiple modulation/coding formats for data rates up to 150 Mbps (300 Mbps in dual chip mode) is a FY01 deliverable under contract with SICOM, Inc.
  - Radiation testing by Sandia will verify the ASIC rad-hard design.



- **Cryogenic Receiver Terminal**
  - A 19 GHz cryogenic receiver with a system noise temperature 6 dB lower than conventional receivers has been developed at GRC and will be demonstrated as the baseline ground terminal for the Direct Data Distribution (D3) experiment project.



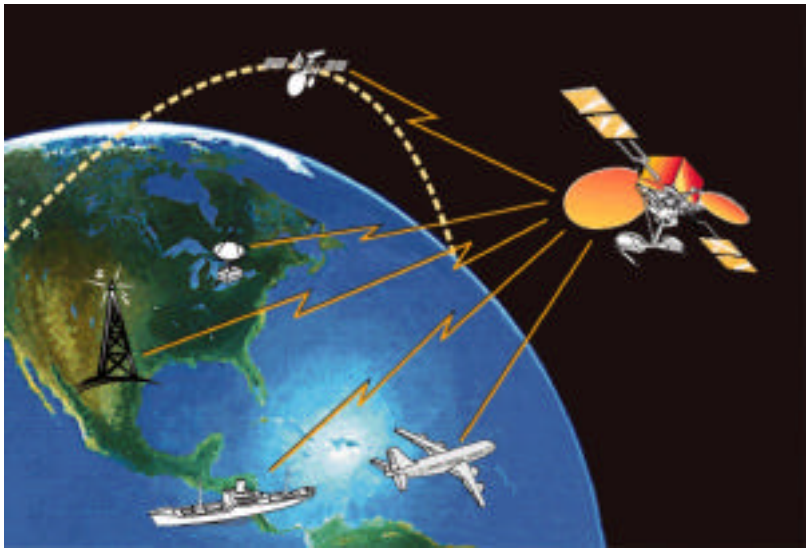
- **K-Band Phased Array Antenna**
  - A 19 GHz MMIC-based, dual beam (circular polarized), scanning array (± 42 degrees) capable of transmitting 622 Mbps per beam directly to ground is scheduled for delivery in FY01 under a cooperative agreement with Raytheon.
  - This agile earth orbit downlink array is only 8x11 in. with a volume of 300 in^3 and a weight of 8 lbs.



Transport Protocols for Space-Based Internets

Technology Goal

- To enable NASA enterprises to realize Internet-based communication needed to transfer information directly to users, provide easy access to mission data and enable interactive communication with the ISS and deep space planetary infrastructures.



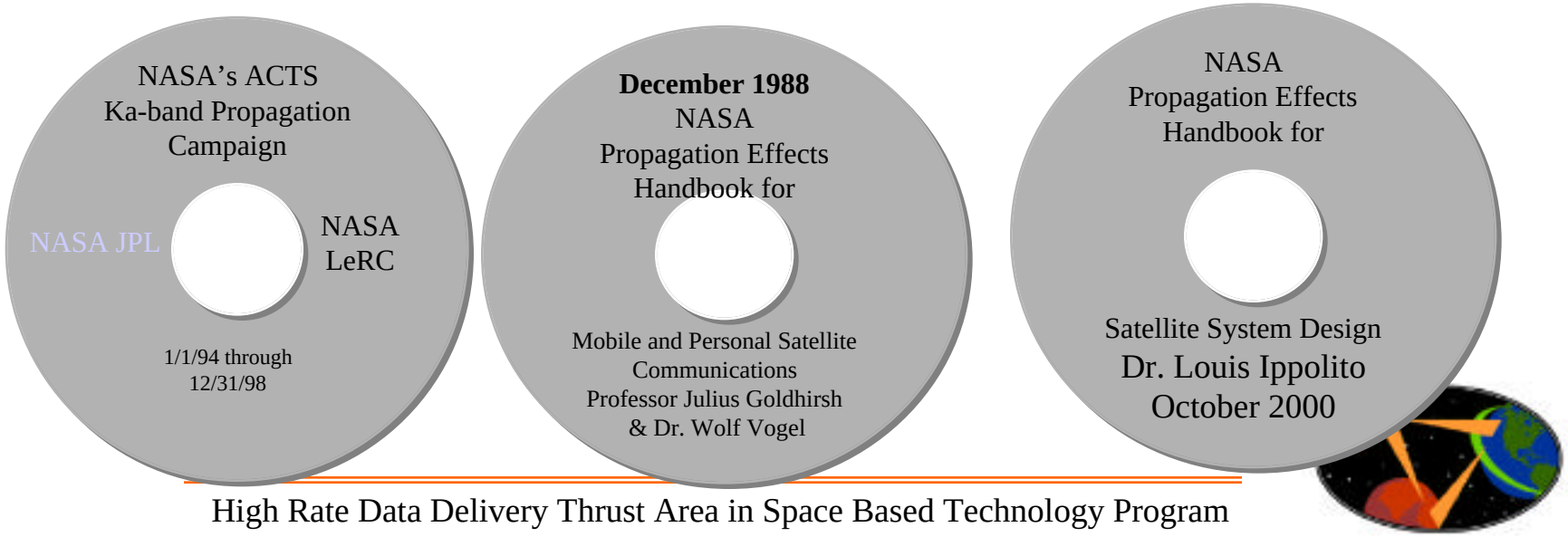
Accomplishment (FY00)

- Multiple IETF Working Groups formed to address
- Realistic network traffic over ACTS link characterized
- Mobile Routing Algorithms and Protocols developed through in-house research, SAA's, and grants.
- RFCs for the round trip time estimation and pacing algorithms for TCP have been accepted by the Internet Engineering Task Force (IETF).
- NASA focused Space-based Internet working group meeting was held at JPL.

Accomplishments

Ka-band Propagation Measurement Campaign

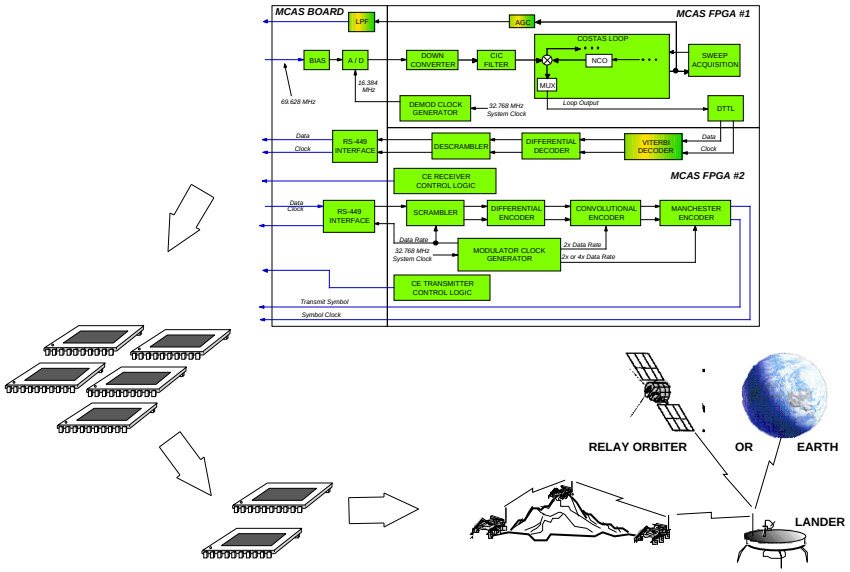
- Significant Accomplishment: Successful completion of a five year Ka-band radio wave propagation campaign through close collaboration between two NASA programs: Advanced Communications Satellite Technology (ACTS) and NASA's Cross Cutting Technology with participation of GRC, JPL, US space industry and over twelve major research universities
- Impact: NASA has made a significant and timely contribution to the effective utilization of Ka-band for broadband services and NASA missions; the agency has received acclaim for her foresight to plan and execute this campaign with enough lead time to have the results ready just at the right time for the US space community
- Products: Five years of high quality Ka-band propagation data collected at seven sites in North America on CD ROMs; update of two premier NASA reference publications with the latest Ka-band performance models; and a cadre of highly sought after Ka-band experts



MICRO COMMUNICATIONS AND AVIONICS SYSTEM (MCAS)

Objectives:

- **Develop multimission UHF transceiver for future low power/mass mission requirements:**
  - **Mass < 150g, Volume < 100 cm^3**
  - **Coherent BPSK (Manch/NRZ, Supp/Resid)**
  - **Convolutional (K=7, R=1/2)**
  - **0.5W Output power, NF < 3dB, stability 10^{-6}**
  - **Hooks for 1 and 2-Way Doppler**
  - **Multiple carrier, FSK, QPSK extensions**
  - **Baseband ASIC: 2.5V, 70 MHz I/F**
  - **Configurable via prom or I^2C port**



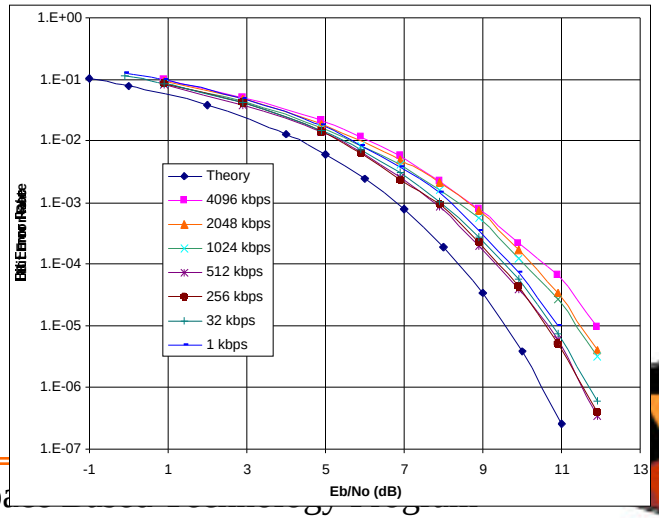
Significant Accomplishments

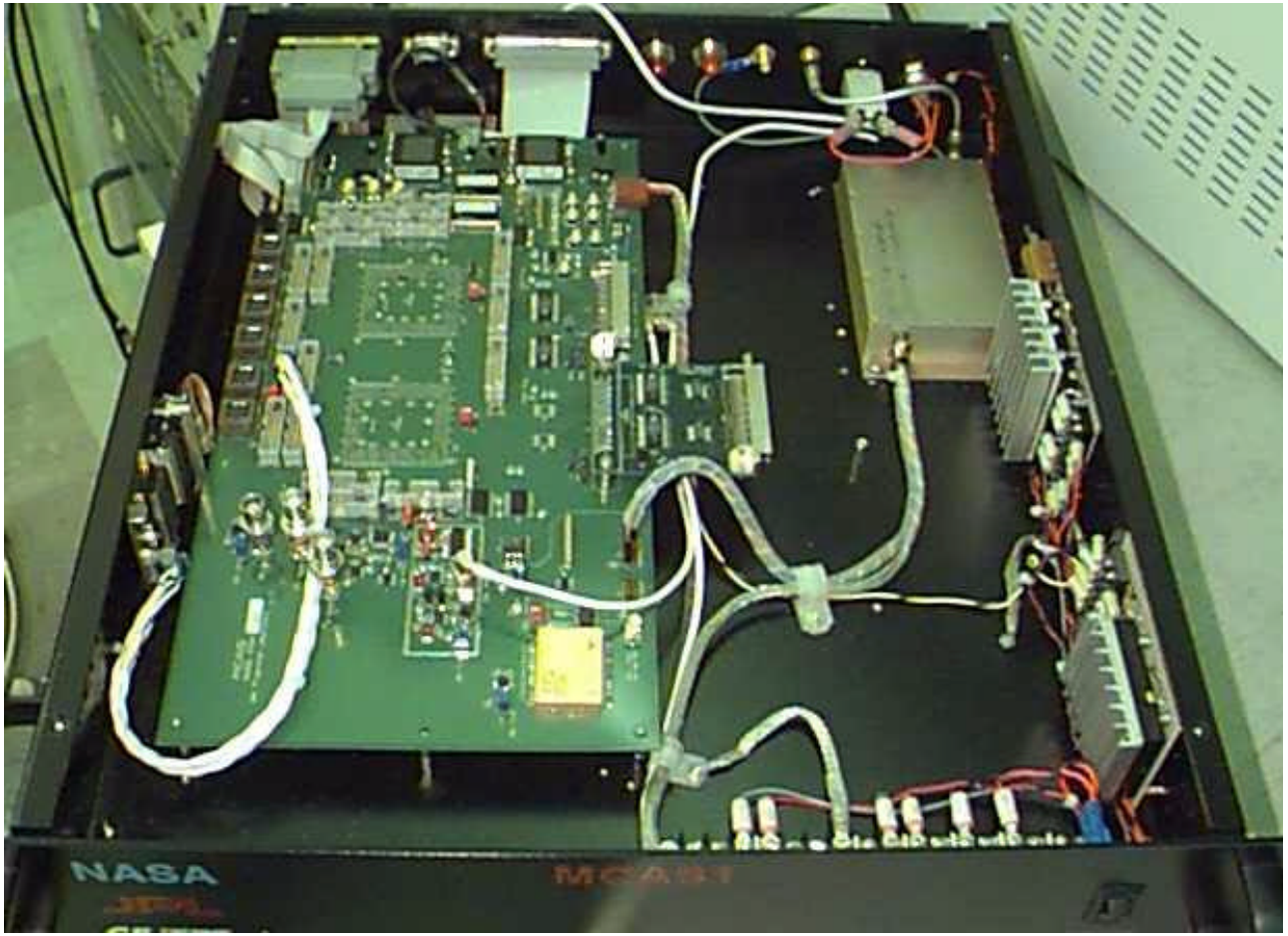
- **Developed Two Complete Functional Chassis**
- **Completed Downconverter and Costas Loop**
- **Completed DTTL (Symbol Timing and Estimate)**
- **Completed Sweep Frequency Acquisition**
- **Completed CE Interface**
- **Completed Modulator**
- **All other subsystems functional in H/W**

Impact:

- **Low power/mass/volume => Enhanced Missions**

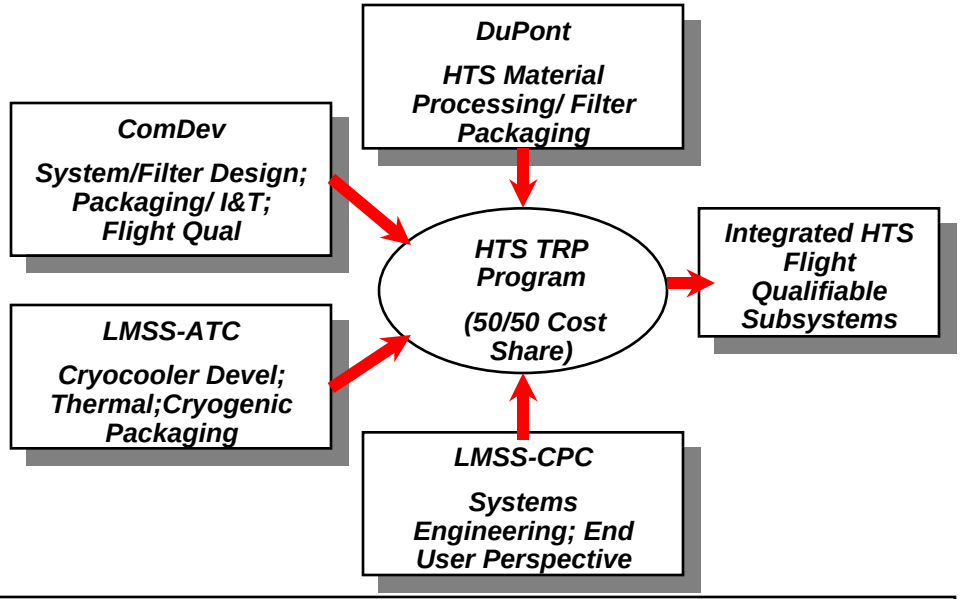
UNCODED PERFORMANCE

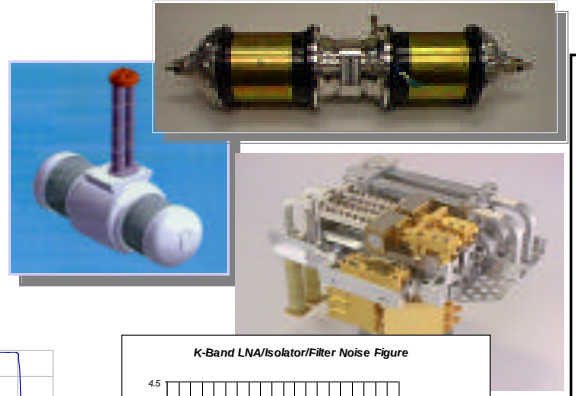


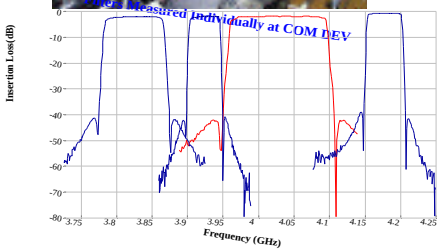

NASA

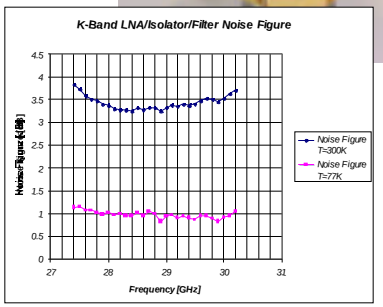
High Temperature Superconductivity Technology Development TRP Program

- **Program Description/Objectives**
  - –**Develop viable HTS RF Space Flight Qualifiable Comm subsystems integrated with highly reliable, compact cryocoolers**
  - –**Advance technologies to enable development/risk reduction of space flight HTS subsystems**
  - –**Demonstrate advantages for HTS subsystems (mass/size reduction, cost savings, performance discriminators) including overhead of cryocooling subsystem**





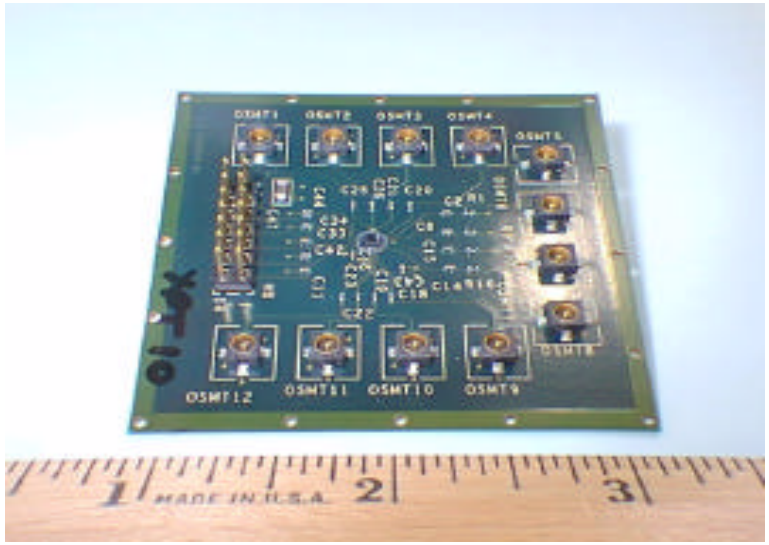




- Program Accomplishments Summary
  - **Compact, efficient Pulse Tube Cryocooler development** (1-3.2W cooling, <23W/W; 3 Kg; Eff. Electronics Controller-1.7Kg; 93% eff.; .98 rel @ 10years)
  - **HTS Material/Filter development** (10 pole self equalized-5,34,41,72,112MHz; packaging; radiation/ environmental testing)
  - **Subsystem #1: 60 Channel HTS IMUX EM & QM development** (>50% mass savings[12-14Kg]; <1/2 size; <1W thermal load; EM unit >5000 hours UUT)
  - **Subsystem #2: Cryogenic Integrated Ka,C band Receiver/HTS Filter EM** (cryogenic Ka LNA, HTS C-band IFA/LNA; up to 2dB reduction in receive noise)
  - **Low thermal loss, low RF loss C and Ka band transitions**

Technology Goal

- Meet NASA's future demand for high data rate on-board processing.



Approach

- Utilize the benefits of SiGe technology to enable the design of extremely high-speed switches with very low power consumption ideal for space hardware.

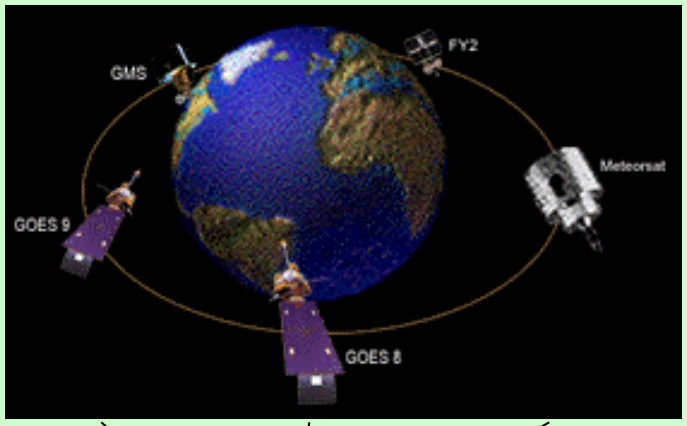
Accomplishment (FY00)

- A 10 Gbps per port, 16 x 16 Silicon Germanium (SiGe) Fast Packet Switch (FPS) was developed that improves the state-of-the-art x8 for bits/port, x12 for total throughput, with 1/2 the power consumption.

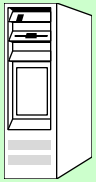
HRIPD Significant Accomplishments

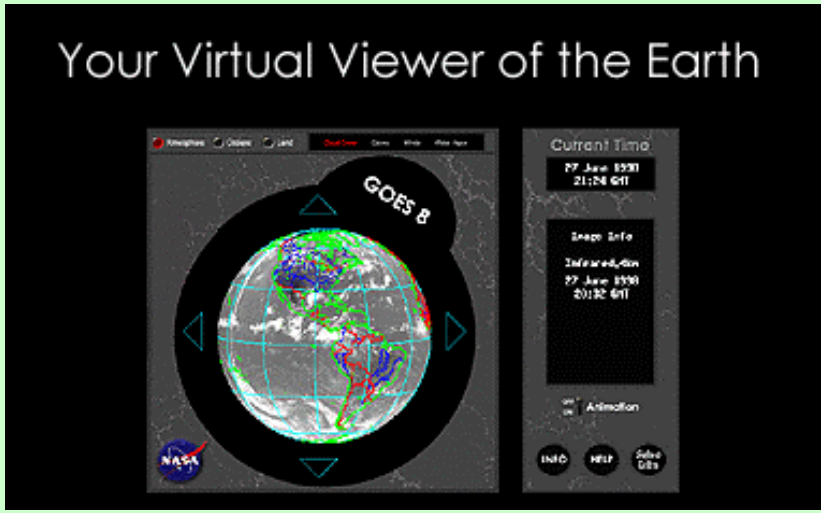
http://edcdaac.usgs.gov/1KM/cro/global/

Selected as Digital Earth prototype, Yahoo cool site



3 Hours





Various Satellites
Data Types & Formats

Processed
Calibration
Mosaic
Projected

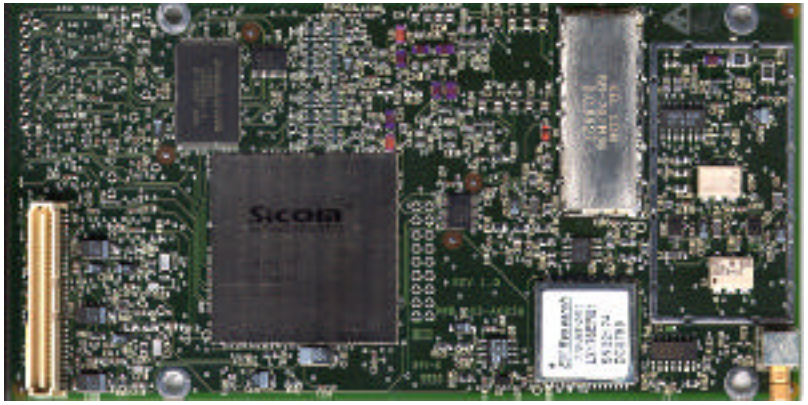
Interactive Display On the Web

- Data Delivery and Display for any Planetary Data with intuitive discovery and access
- Digital Earth Prototype and testbed for Web Mapping Testbed protocols.

High Rate Radiation Hardened Digital Modem

Technology Goal

- Meet NASA near Earth mission requirements for high rate digital communications and future multi-Gbps throughput satellite communication systems.



Approach

- Develop a high rate, bandwidth efficient, flight qualifiable modem.
- Fabricate a radiation-hardened, programmable modulator ASIC that is the building block to achieve a solution for flight-qualifiable high data rate modems.

Accomplishment (FY00)

- A radiation-hardened ASIC configurable to meet multiple modulation/coding formats for data rates up to 150 Mbps (300 Mbps in dual chip mode) is a FY01 deliverable under contract with SICOM, Inc.
- Radiation testing by Sandia will verify the ASIC rad-hard design.

Summary

- Earth Science Enterprise requirements were addressed through relevance reviews of NAR and NRA tasks
- Communication architecture development/analysis tasks were jointly initiated to address long term ESE vision
- Technology Infusion through NMP and AIST Programs took place
- Contributed through participation in workshops/closer contacts developed within the ES community
- SBIR subtopics were developed